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Microtremor measurement-based prediction of ground shaking in Kathmandu Valley of Nepal

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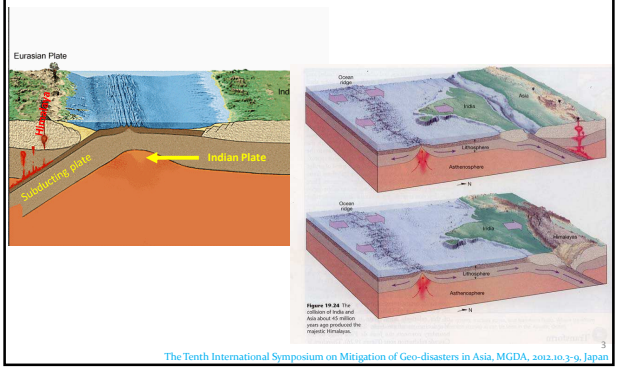
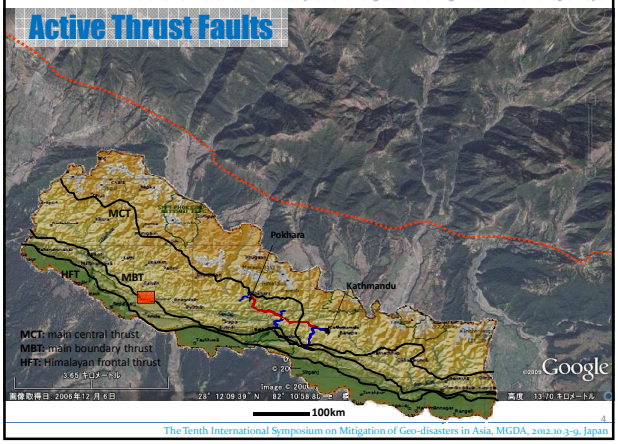
Presentation Content

- Background information (Nepal and Kathmandu Valley)
- Microtremor Survey
- Analysis and Results
- Predominant period distribution map
- Double predominant period
- Concluding Remarks

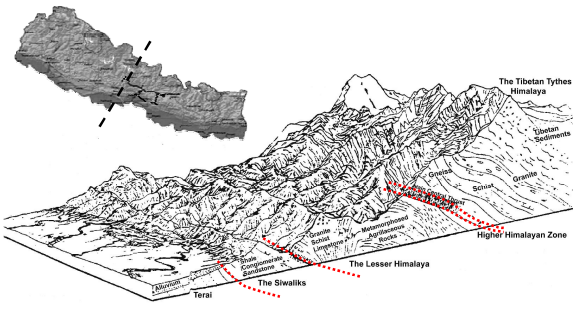
Why Earthquakes in the Nepal?



Active Thrust Faults

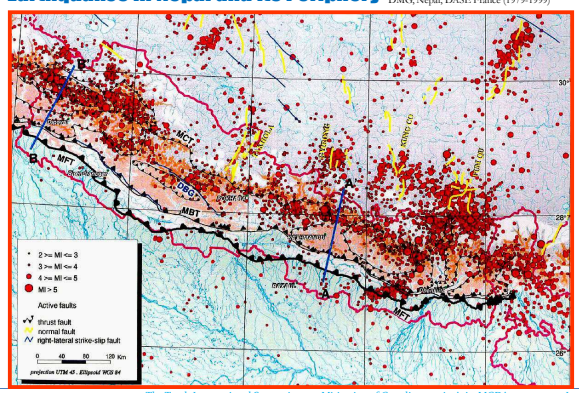


Nepal: Geology and Geomorphology

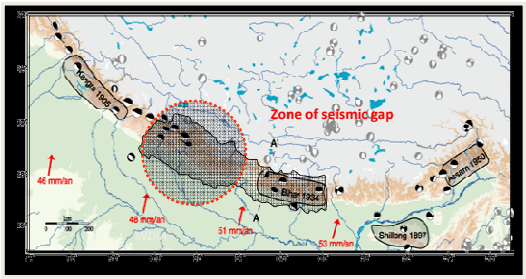


Earthquakes in Nepal and its Periphery

DMG, Nepal, DASE France (1979-1999)



Major Earthquakes in Nepal Himalayan Region and Zone of Seismic Gap (Avouac et al, 2001)



Distribution of earthquake near Kathmandu (Source: JICA 2002, UNDP/UNCHS 1994, Pandey, M.R. et al.., 2001)

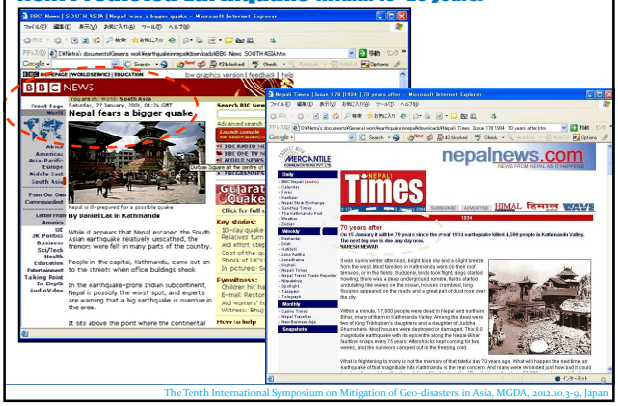
Recorded Earthquake History of Nepal

Date	Magnitude	Intensity	Latitude	Longitude	Epicenter dist. (Km)	Assumed PGA (gal)
1255/6/7	7.7(assumed)	X	NA	NA	Near KTM	NA
1408	NA	X	NA	NA	Near KTM	NA
1681	7 (assumed)	IX	NA	NA	Near KTM	NA
1810	NA	IX	NA	NA	NA	NA
1833	7		28	85	38	137
1833/8/26	7	X	27	85	84	75
1833/10/4	7	IX	27	85	151(Kalaiya)	47
1833/10/18	7	VIII	27	84	India	NA
1866/23/05	7	X	27.7	85.3	Kathmandu	NA
1869/7/7	7		28	85	45	121
1934/1/15	8.4	IX-X	27.55	87	177 (North of Chainpur)	188
1936/5/27	7	NA	28.50	83.5	199	38
1954/9/4	6.5	NA	28.30	83.8	163	34
1988/8/20	6.5		26.75	86.62	167 (Udayapur)	36

Note: NA here represents data not available

When ??

Next Predicted Earthquake (within 10~20 years)

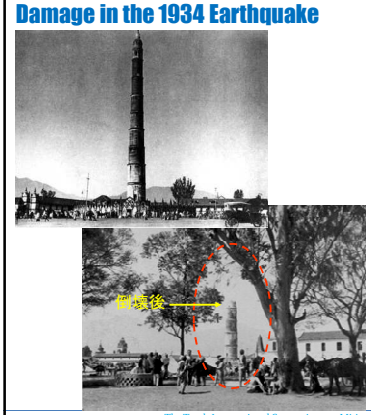


Talking of Extremity

- Transportation
  - Roads, Bridges, Airports
  - Urban roads
- Glacier Lakes
  - Morain dam failure, debris flow, flooding
- Landslides
- Communication
- Hospitals
- Schools
- Government Buildings (Presidential Palace, Singh Durbar, Ministry and Ministerial Department Buildings, etc.)

and so on

Damage in the 1934 Earthquake



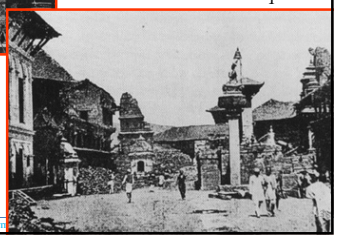
Fall of Dharahara in 1934 earthquake

Dharahara at present

Ghantaghar and Kathmandu Durbar Square

Bhaktapur Durbar Square (1934 Earthquake)

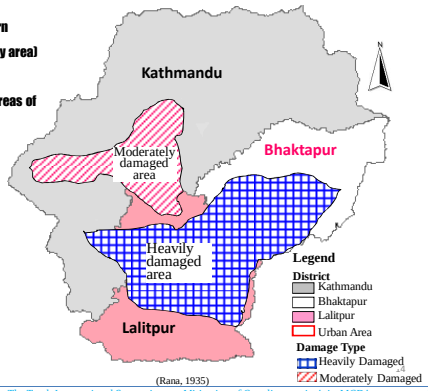
After the earthquake



Before the earthquake

Damage distribution in 1934 Earthquake in Kathmandu Valley

- Southern and eastern parts (Bhaktapur city area) were damaged very heavily than other areas of the valley

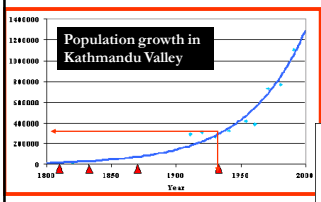


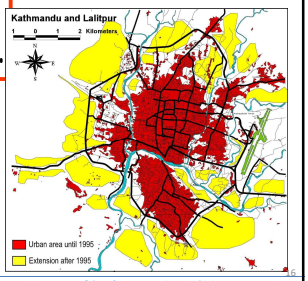
(Rana, 1935)

Basic information (Kathmandu Valley)

- Three main cities: Kathmandu, Lalitpur, Bhaktapur
- Resident Population: About 5 million (estimated)
- Altitude: 1,300 (average)
- Estimated human death: 40,000 – 100,000
- Estimated Injury: 200,000
- Major Earthquake Recurrence Period: 80-100 years
- Minor Earthquake Recurrence Period: 10-20 years
- Less than 3 Richter Scale Earthquakes: Several times a year

Population Growth





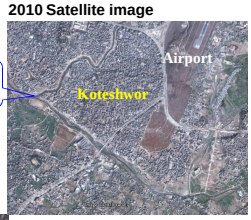
Rapid population increase

1964 Satellite image

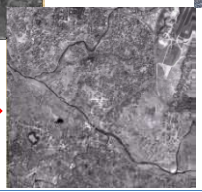
(Population: 308,000)

Confluence point of Bagmati and Manohara rivers

2010 Satellite image



(Population: 2.5 million)



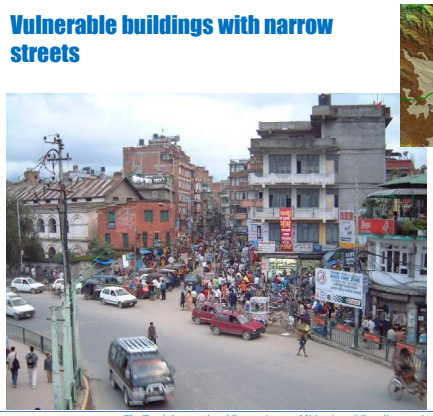
2001 Satellite image
Population: 1.1 million

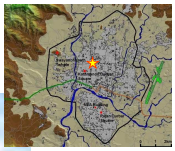
At Present

Old buildings/houses

Slender buildings/houses
(Improper design??)

Vulnerable buildings with narrow streets

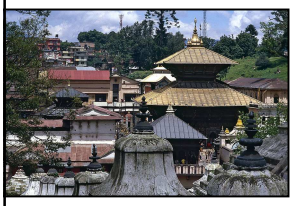


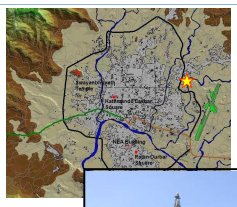


Historical Monuments (World Cultural Heritages)

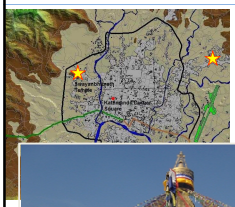
- Seven World Cultural Heritage Sites in Kathmandu Valley
- Together with the environmental degradation and scenic deterioration following the urbanization, the earthquake disaster risk has increased greatly
- Disaster risk: Earthquake and Landslides

Pashupatinath Temple





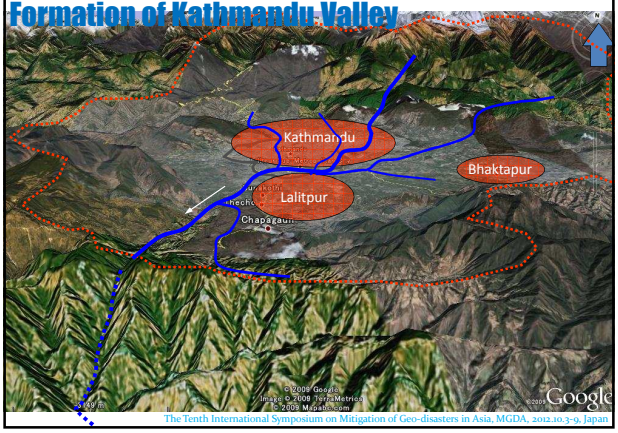
Changunarayan Temple



Bouddhanath Stupa

Swayambhunath Stupa

Formation of Kathmandu Valley



Formation of Kathmandu Valley

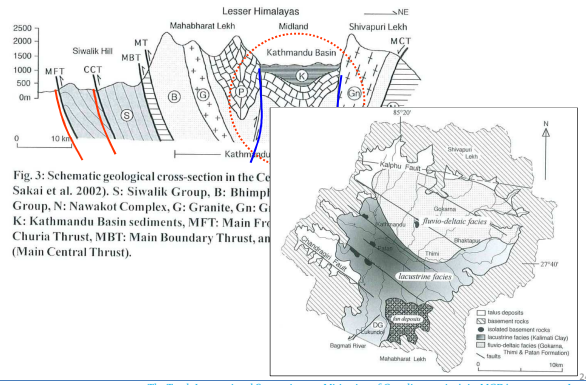
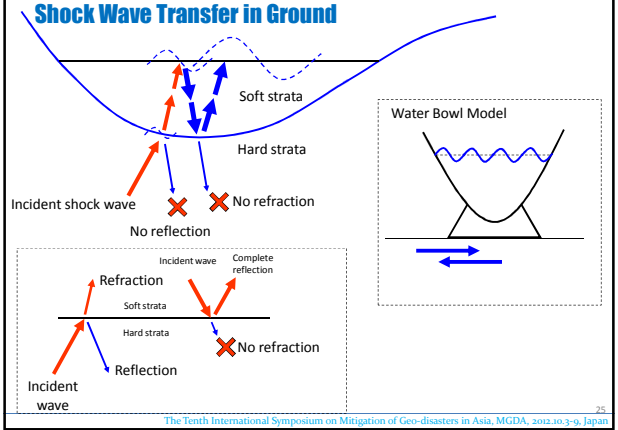
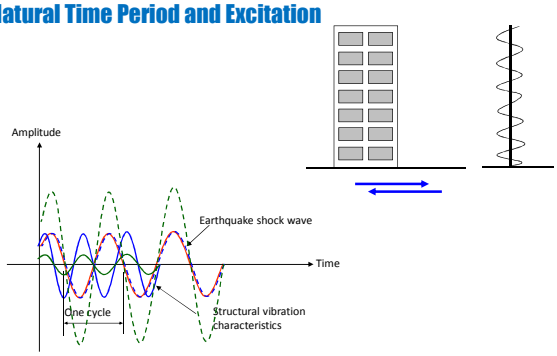


Fig. 3: Schematic geological cross-section in the Ce
Sakai et al. 2002). S: Siwalik Group, B: Bhimpl
Group, N: Nawakot Complex, G: Granite, Gn: G
K: Kathmandu Basin sediments, MFT: Main Fr
Churia Thrust, MBT: Main Boundary Thrust, an
(Main Central Thrust).

Shock Wave Transfer in Ground



Natural Time Period and Excitation



Building Structures

- Brick masonry……Recently: Cement mortar, Old structures: Brick powder mortar, lime mortar, mud mortar
- Reinforced concrete……RCC framed structure, Concrete block or brick masonry walls

Major Problems

- Earthquake resistability of hospitals
- Secondary disaster (Fire, aftershocks, etc.)
- Evacuation space (not properly identified)
- Lifeline damage……water pipeline (very old), power line, liquefaction-induced road damage, etc.

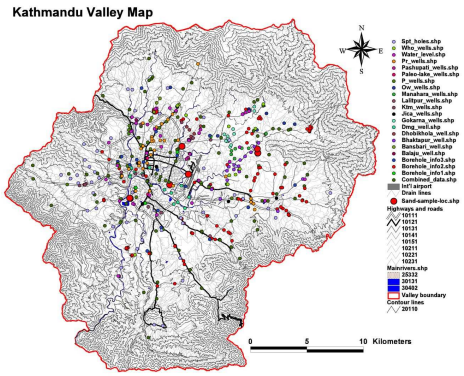
Earthquake Disaster Risk in Kathmandu Valley and Technical Studies

- UNDP Study (Year 1992)
- An Integrated Study of Earthquake Disaster Mitigation in Kathmandu Valley by JICA (Year 2001)
  - Expected Earthquakes (Three cases)
  - Liquefaction Analysis/Prediction
  - Slope Failure Prediction
  - Lifeline Damage Prediction (Power line, Water pipeline, Roads, Bridges, Telephone line, etc.)
  - Building structural Damage Estimation
  - Human Death Estimation
  - Identification of Evacuation Path and Evacuation Space

Geotechnical Study Plan at Ehime University

- Geo-info Database Preparation and Application
- Microtremor Survey and Earthquake Motion Analysis/Simulation
- Installation of Earthquake Accelerometers, Data Acquisition
- Groundwater Flow Simulation
- Ground Subsidence Prediction, etc.

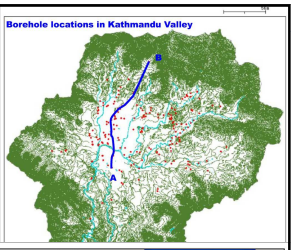
Status of Borehole Exploration in Kathmandu Valley (From 1980 to 2002)

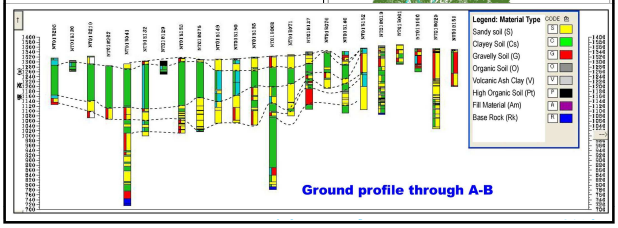


Geo-info Database

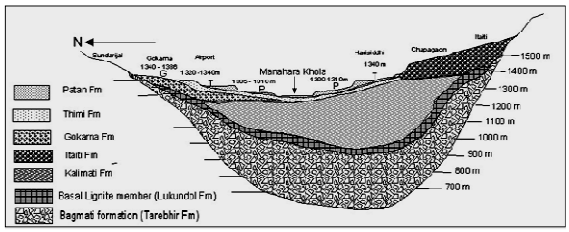
Borehole Data :

Boreholes for various purposes





Geological Strata of Kathmandu Valley Ground (Sakai et al. 2001)



Microtremor Survey for Damage Prediction

Microtremor: vehicle movement, explosion, factory vibrations, etc.

Highly sensitive accelerometer

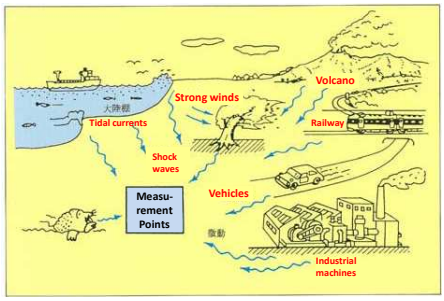
Measurement → Data Analysis → Fourier Analysis → H/V Spectrum → Natural time period estimation

H: Horizontal

V: Verticle

Natural time period → Damage Prediction

Microtremor sources

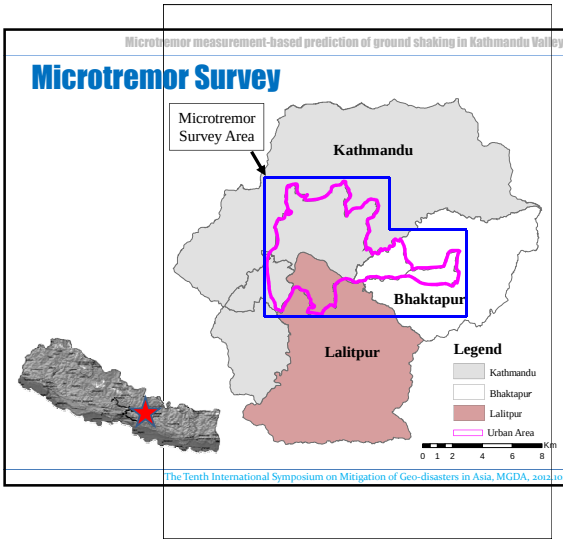


(From Tokyo Soil Research)

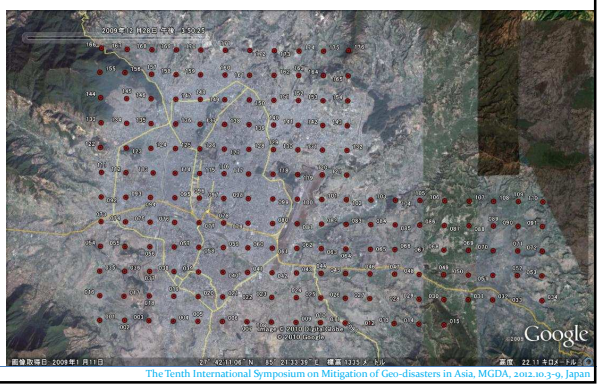
Kathmandu:

- Vehicle movement
- Winds
- Industrial machines
- etc.

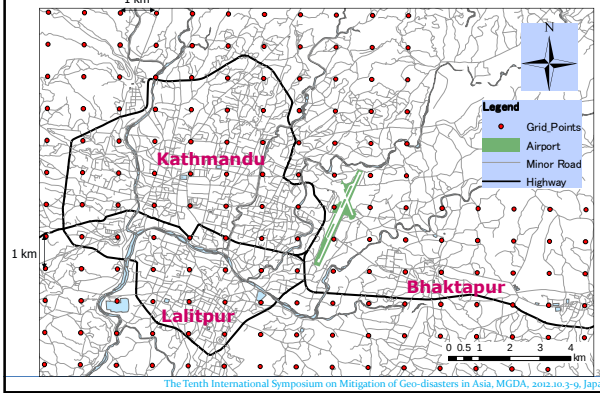
Microtremor Survey



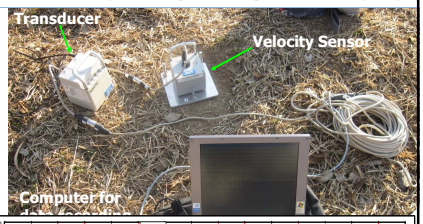
MT Survey in Kathmandu Valley



Location for MT Survey in KV



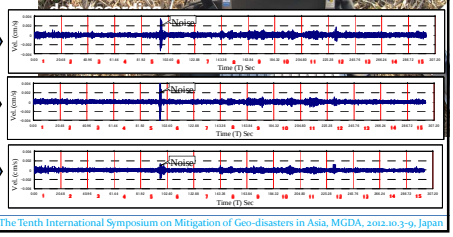
Device and Data



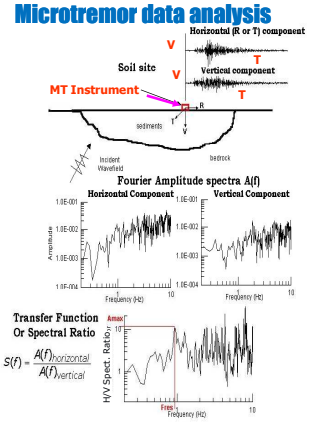
North- South (NS) component data

East- West (EW) component data

Vertical (UP) component data



Microtremor data analysis



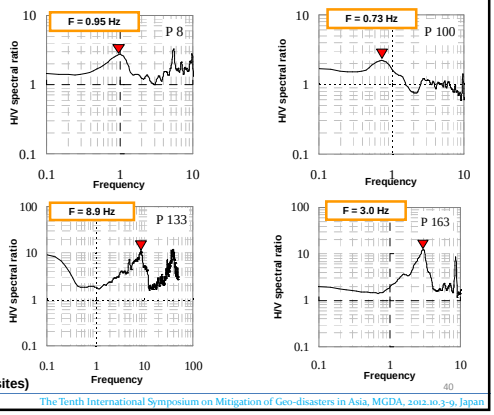
Three velocity components (EW, NS , and UP) are measured (Time domain)

Fourier Analysis

Fourier Amplitude Versus Frequency (Frequency domain)

Frequency correspondences to maximum value of H/V ratio gives the predominant frequency of the site

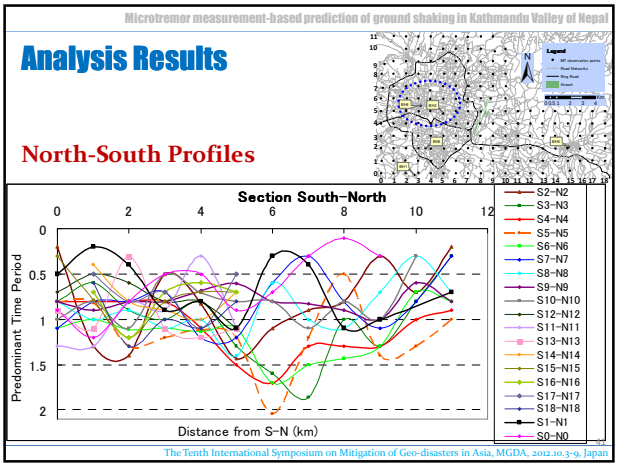
Analysis



(F: Predominant frequency of the sites)

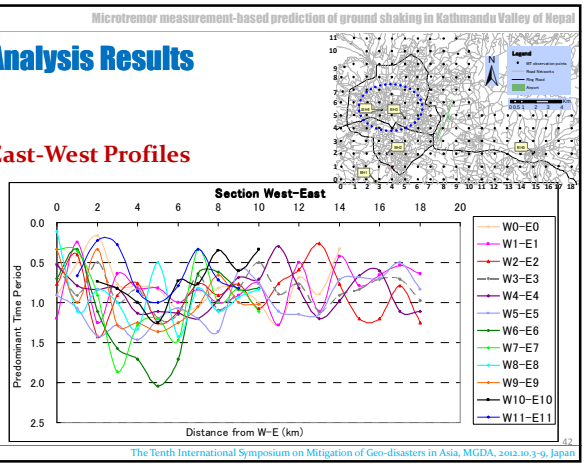
Analysis Results

North-South Profiles



Analysis Results

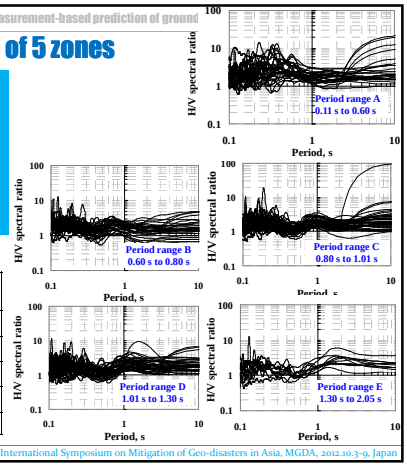
East-West Profiles



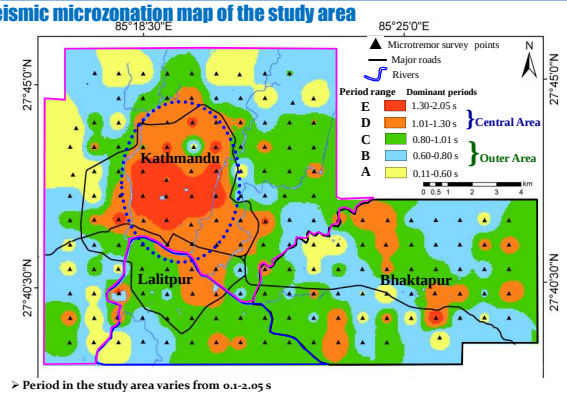
H/V spectral ratio of 5 zones

- The study area is divided into five different range of predominant periods using natural break technique, which regroups similar values together and represents the distribution properly

Predominant period range	Description of zone
A	0.11 s to 0.60 s
B	0.60 s to 0.80 s
C	0.80 s to 1.01 s
D	1.01 s to 1.30 s
E	1.30 s to 2.05 s

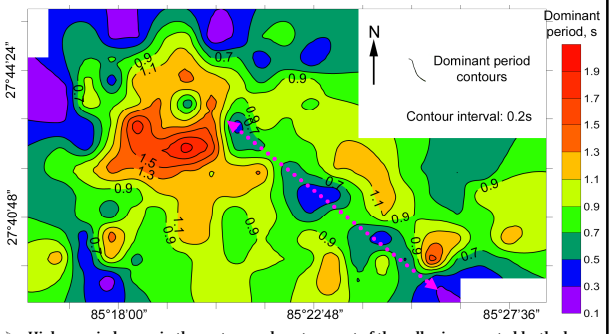


Seismic microzonation map of the study area



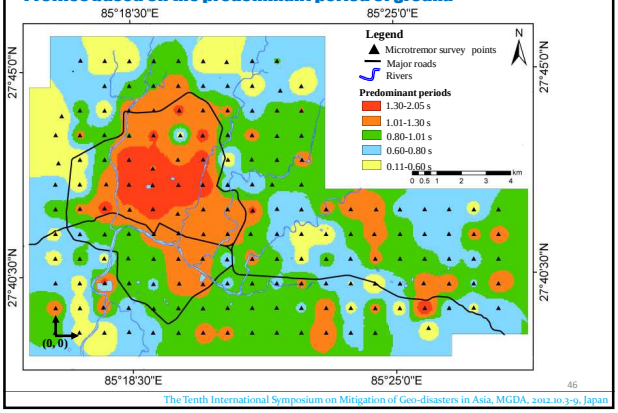
- Period in the study area varies from 0.1-2.05 s
- Period in central part varies from 1-2 s, which covers about 30% of the urban area of the valley

Predominant period contours for the Kathmandu Valley

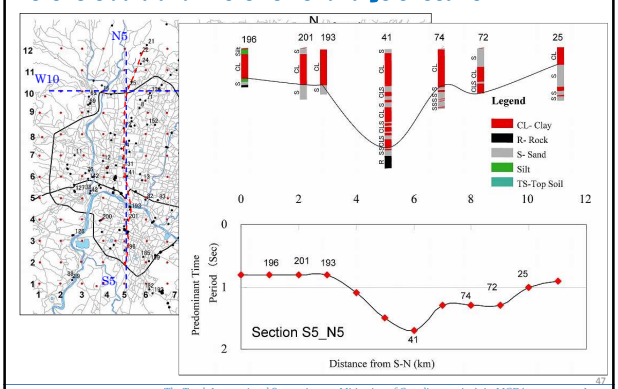


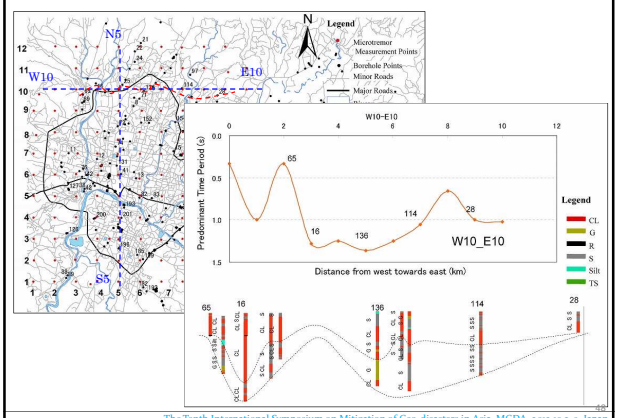
- Higher period range in the eastern and western part of the valley is separated by the long low period line extended from north-west to south-east in the valley

Profiles based on the predominant period of ground

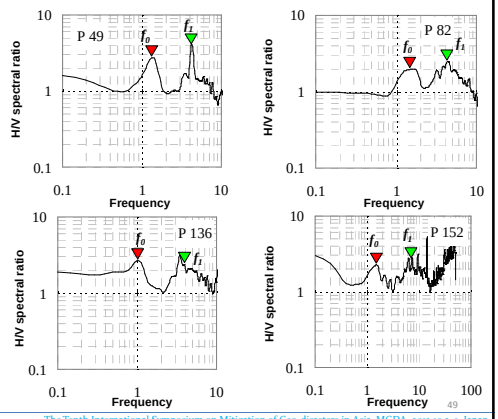


Borehole data and microtremor analysis results





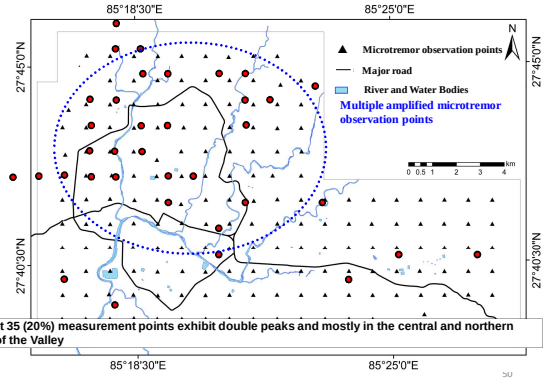
Multiple resonant frequency



f_0 : first resonant frequency of the sites

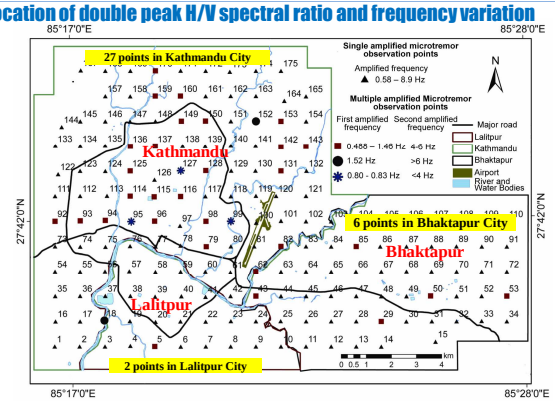
f_1 : second resonant frequency of the sites

Location of double peak H/V spectral ratio



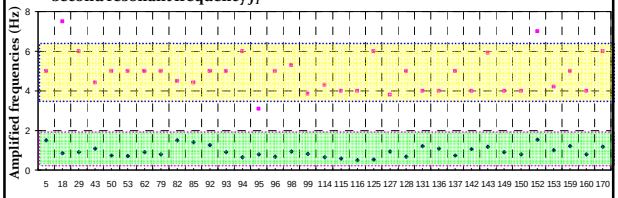
About 35 (20%) measurement points exhibit double peaks and mostly in the central and northern part of the Valley

Location of double peak H/V spectral ratio and frequency variation



Distribution of multiple resonant frequencies

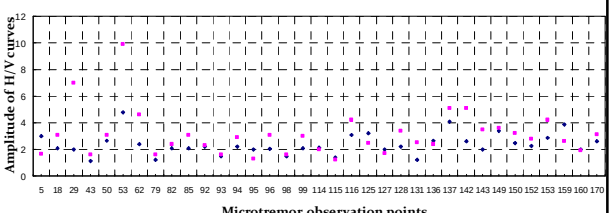
- First resonant frequency f_0
- Second resonant frequency f_1



- First resonant frequencies vary from 0.48 Hz to 1.52 Hz
- Second resonant frequencies vary from 3.1 Hz to 7.5 Hz, however mostly vary from 4 Hz to 6 Hz
- The ratio of second to first resonant frequency is found about 5

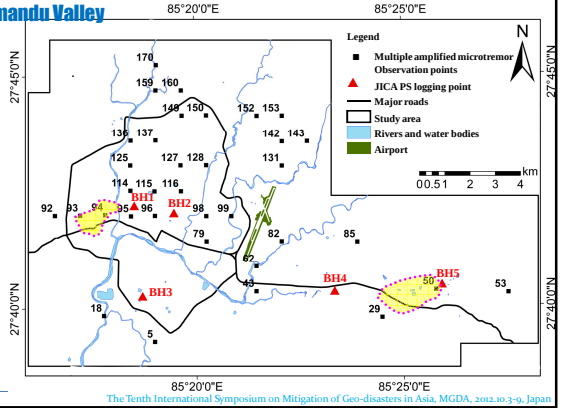
Amplitude of multiple resonant frequencies

- Amplitude of first resonant frequency A_0
- Amplitude of second resonant frequency A_1

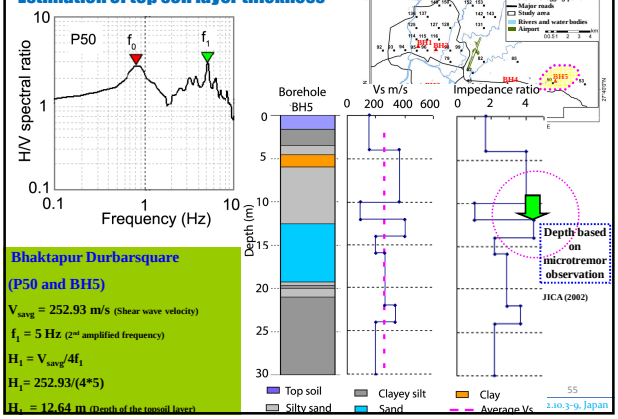


- Amplitude of the second resonant frequencies are found higher than the amplitude of the first resonant frequencies in some of the location

Location of double resonance area and JICA (2002) PS logging sites in Kathmandu Valley



Estimation of top soil layer thickness



Bhaktapur Durbarsquare

(P50 and BH5)

V_{savg} = 252.93 m/s (Shear wave velocity)

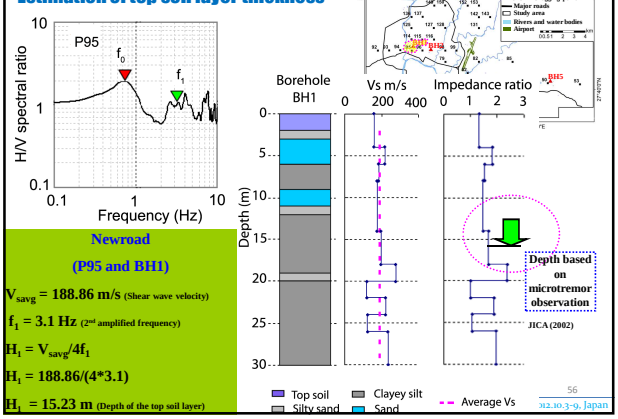
f_1 = 5 Hz (2nd amplified frequency)

$H_1 = V_{savg}/4f_1$

$H_1 = 252.93/(4*5)$

H_1 = 12.64 m (Depth of the topsoil layer)

Estimation of top soil layer thickness



Newroad

(P95 and BH1)

V_{savg} = 188.86 m/s (Shear wave velocity)

f_1 = 3.1 Hz (2nd amplified frequency)

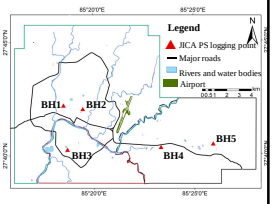
$H_1 = V_{savg}/4f_1$

$H_1 = 188.86/(4*3.1)$

H_1 = 15.23 m (Depth of the top soil layer)

Estimation of top soil layer thickness in the Kathmandu Valley

SN	Borehole Location	Bore hole ID	Average shear wave velocity (m/sec)	Average shear wave velocity upto 30 m depth for Kathmandu Valley (m/sec)
1	New Road	BH1	188.87	246.87
2	Singha Durbar	BH2	310.85	
3	Jawolakhel	BH3	247.33	
4	Thimi	BH4	234.40	
5	Bhaktapur	BH5	252.93	



- Average shear wave velocity based on JICA study for Kathmandu Valley (based on 5 PS logging sites) = 246.87 m/sec (JICA, 2002)
- The second resonant frequency varies from 3.1 Hz to 7.5 Hz
- The depth of the top soil layer responsible for amplification of soil = 10 m -20 m

Concluding Remarks

- Predominant period in the urban cores and peripheral settlements of the Kathmandu Valley varies from 0.1 s to 2.0 s, and that the period gradually decreases from a higher value in the central part of the valley to a low value in the outskirts.
- The trend of period variation is found to follow the distribution of sediment depth in the valley.
- In the central part, tall buildings and long-span bridges are susceptible to damage, while it is opposite in the outskirts.
- The investigation results show that two amplified frequencies appear at about 20% of the measurement sites, which are mainly distributed in the central and the northern part of the basin
- The first amplified frequencies vary from 0.5 Hz to 8.9 Hz, whereas the second amplified frequencies vary from 3.1 Hz to 7.5 Hz, in which most of them vary from 4 Hz to 6 Hz
- Depending on the area, especially in the central and northern part, the top 10-20 m of the sediment layer plays an important role in making the second resonant effect in the Kathmandu Basin

Thank you